AASERT
Model Evaluation and Model-model Intercomparison in the North Atlantic Ocean

Final Report

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Executive Summary

The award (Grant No. N00014-93-1-0758) was to support a student at Rutgers University while working under the supervision of Prof. D. Haidvogel.

The fellowship was granted to Scott M. Durski, that at the time had just received a Masters of Engineering at the Department of Civil, Environmental and Coastal Engineering from the Stevens Institute of Technology.

The student has successfully completed all the requirements for a doctoral degree in Oceanography at Rutgers University and is expected to graduate by the end of the academic year 97-98.

Scott Durski has proven to be a bright and reliable student. He has shown a high learning capability, a quick understanding of the problems, and the ability to make independent decisions without losing focus of his main assignments.

The enclosed activity report summarizes S. Durski achievements.

Activity Report
by
Scott M. Durski

Abstract

My research over the past four years has focussed on three areas. Foremost of which is modeling summer circulation in the New York Bight (my thesis work). I have also spent time developing an idealized basin scale physical-biological model and studied the New York Bight/Hudson Estuary complex through analysis of AVHRR satellite imagery. Scholastically, I have taken eleven courses ranging from Boundary Layer Meteorology to Biological Oceanography. I passed my PhD. qualifying exam 2 years ago and my thesis proposal last year. I gave a talk Last Fall at the American Geophysical Union Meeting and a poster this summer at the Gordon Research Conference on coastal ocean circulation. I also attended a two week workshop on phytoplankton population dynamics at the Isaac Newton Institute of Mathematical Studies, Cambridge last year.

New York Bight Modeling Research

Background

The New York Bight modeling research that is the focus of my thesis is aimed at furthering our understanding of summer upwelling dynamics along the New Jersey coast. Prevailing winds from the south tend to produce offshore transport in the surface waters off New Jersey and upwelling of cold water at the coast. Although the phenomena is transient (lasting anywhere from 2 to 10 days) it tends to reoccur numerous times over the course of a summer. The intensity of the upwelling varies spatially also. On numerous occasions patches of more intense upwelling appear along the coast at fixed positions. These upwelling centers have been suggested to be associated with particularly shallow regions in the coastal bathymetry. It has also been noted that these regions appear correlated with regions of recurrent low dissolved oxygen in the bottom waters (In the past such hypoxic and anoxic events have had a significant economic impact on the New Jersey shellfish industry). In my thesis work I am developing a numerical model to further understand the dynamics of these upwelling centers and to try to ascertain their impact on the biological and chemical environments of the coastal zone.

A wide array of physical, biological and chemical parameters are measured each summer by scientists at the Institute of Marine and Coastal Sciences in a region along the southern coast of New Jersey centered at the Long-Term Ecosystem Observatory (LEO-15). These extensive observations offer the opportunity for extensive model-data comparison. They also provide data for initialization and forcing the coastal model.

Two-dimensional model sensitivity experiments.

The numerical model I am using is the S-coordinate Rutgers University Model (SCRUM version 3.0). Initial sensitivity studies focused on the two-dimensional (x-z vertical section) response of the system to upwelling favorable winds. These initial sensitivity studies revealed the role that bottom topography, bottom friction and vertical mixing played in determining the development of the upwelling zones. They showed, among other things, how the position (offshore) of the maximum Ekman divergence was altered by the presence of shallow embankments near the coast. I presented the results of these two-dimensional sensitivity studies at the American Geophysical Union meeting last December.

The three dimensional model

Following the AGU meeting I developed the three dimensional New York Bight application of SCRUM. The grid domain extends from Chincoteague Bay, Deleware in the south to Montauk Point, Long Island in the North. It extends from the coast to approximately the 60 meter isobath. Grid resoultion is better than 1 km in the offshore direction along most of the New Jersey coast. Initial stratification for my three dimensional sensitivity studies were obtained from an offshore CTD cast considered representative of typical summer condtions. Wind forcing was based on hourly meteorological data from the Rutgers Marine field station in Tuckerton, NJ when available or from the NOAA Deleware Bay buoy when not.

The grid domain included three boundaries (two cross-shelf, one alongshelf) which needed to be treated with open boundary conditions. A wide variety of boundary conditions were implemented in SCRUM and compared. As might be expected different combinations of boundary conditions were found to behave best under differing forcing conditions. While Orlanski radiation conditions worked well for determining the tidal response of the domain, they were found to be inadequate for the wind forced case. For wind forcing without tides a reduced physics boundary condition on the barotropic velocity components was found to perform quite well but this condition did not work well with tides. Because the phenomena of interest is wind driven, and because no boundary condition could be found that worked equally well with tides and wind, a set of boundary conditions including the reduced physics on the barotropic mode was chosen.

Three-dimensional model sensitivities

The first sensitivity test performed with the three dimensional model was aimed at determining the role of bathymetry in the development of upwelling centers along the New Jersey Coast. Model runs were performed with realistic and smoothly sloping bathymetry. Comparison of the results revealed that the upwelling centers would not develop without alongshore variability in the topography. The runs also showed that the upwelling centers formed at topographic highs along the coast as had been suggested by earlier idealized studies (Glenn et al, 1996)

Vertical turbulent mixing parameterizations are often used in the coastal ocean but seldom are comparisons of the different schemes performed in this complex

environment. A secondary goal of my thesis work is to make a determination through model/data comparison, as to which turbulent mixing parameterization best reproduces the upwelling circulation. As one step in this direction sensitivity tests were performed to compare three mixing schemes ([MY] Mellor and Yamada, 1982) , [PP] Pacanowski and Philander, 1981 and [LMD] Large, McWilliams and Doney 1994). Under typical upwelling winds the LMD model and the PP model tended to mix the thermocline deeper than the MY (level 2). The MY model therefore produced higher offshore surface currents and a stronger divergence (greater upwelling) at the coast. In addition to upwelling conditions the models were also run under very high wind stress conditions (corresponding to tropical storm Bertha, which past the New Jersey coast in the summer of 1996). Under such forcing both PP and MY mixed far less than did LMD. These results affirm the sensitivity of the dynamics to the choice of vertical mixing scheme.

The early sensitivity runs were performed in a model domain which excluded the Hudson and Deleware estuaries. As a test of the influence of these bays, special open boundary conditions were applied along the edge of the grid domain where the estuarine outflows would normally occur. These open boundary conditions supplied an inflow/outflow of water opposing sea level change at the mouth of the estuaries. This significantly altered the development of upwelling regions and interrupted the advection of water along the coast. (I presented the above sensitivity studies in a poster at the Gordon Research Conference on coastal ocean circulation in June.)

Because the circulation was found to be sensitive to the presence of estuaries I generated a new masked model grid to include a significant portion of Newark Bay (Hudson estuary) and Deleware Bay. I also implemented a new set of boundary conditions on the upstream end of these bays to 'conservatively' add freshwater to the domain. Model runs with the new masked grid and riverine inflow have allowed me to study the interaction of the upwelling circulation with the estuarine plumes.

An issue which is closely tied to vertical mixing is that of surface stresses and fluxes. I performed sensitivity test to determine how the model response changed with moderate changes in the net surface heating. Notable differences in the position and shape of the upwelling front were observed under the different forcing conditions. Model sea surface height data was also analyzed and compared to tide gauge data along the east coast. This showed that the model reproduced the sea surface slope under some conditions but not all. With the above sensitivities in mind, I have made an effort to collect a more complete meteorological data set for the New York Bight. Data has been collected from nine NOAA buoys and eighteen airports in eastern coastal region. The averaged hourly data collected has been converted into surface stresses and heat fluxes by implementing a slightly modified version of the TOGA-COARE algorithm (Fairall et. al., 1996). The resulting station data is being objectively analyzed to create grided surface stress and flux fields.

Many of the model refinements are in place at this point. Several features which still need to be added include diagnostics and drifters. Once these are complete a rigorous

model/data comparison will be performed along with a detailed study of the phenomenology of the upwelling.

Coupled Physical-Biological Modeling

In addition to my New York Bight modeling I have been studying coupled physical-biological dynamics. I have been looking at the behaviour of simple predator-prey (phytoplankton-zooplankton) systems coupled to two dimensional ocean circulation models. The goal is to examine the dynamics of these systems under realistic flow conditions. Often such highly idealized non-linear models are studied under very idealized flow conditions. 'Realistic' ocean models often incorporate multi-component linearized biological models. Incorporating the few-component non-linear biological models to more realistic physical systems allows us to learn how much what we learned in the idealized studies extends to the real world.

The ocean model being used for this study is the two dimensional spectral finite element model (SEOM) in its parallelized version. The model domain currently being used is a rectangular basin rougly 3500 km by 2500 km. A double gyre is set up in the basin through a latitudinally varying wind stress. An intense jet flows eastward from the western boundary generating eddies and meanders in the flow. The biological model is an extension of that used by Pascual(1993). She found that while the predator-prey system alone exhibited limit cycle dynamics, when spatially coupled through a laplacian diffusion term, the populations behaved chaotically. My current research seeks to extend this work to determine the effect realistic 2 dimensional advection has on this system. Model runs so far have focused on the spatial scale of the variation in growth rate of the prey and on exploring the effects the diffusion term alone has on the populations. Due to the complexity of the behavior that develops, diagnostic tools for analyzing the model results need to be developed.

Remote Sensing of the New York Bight Apex

Early in my PhD, I took a course on remote sensing of the oceans, for which I wrote a paper on satellite AVHRR observations of the New York Bight and Hudson estuary. This paper grew into a more detailed study over the next year (Durski, 1996). Fifteen months of AVHRR thermal and visible data was studied. Seasonal patterns of surface heating and cooling were observed along with circulation patterns specific to the different seasons. An interesting feature of the unstratified season which was repeatedly observed was an intrusion of warm water along the contours of the Hudson Shelf Valley in response to winds from the Northwest. Bottom currents in the valley had been noted to behave in this manner but the extension of this onshore current to the surface had not been previously noted. During the spring,summer and fall, when the waters were stratified, the Hudson estuary plume was sometimes observable in the apex. However, the estaurine outflow was only distinguishable when estuarine and coastal surface water temperature differed significantly (generally in the spring and fall). A feature which was repeatedly observed during the summer season was a region of

intense vertical mixing located near Rockaway Point at the estuary mouth. This vertical mixing was confirmed by CTD data from a cruise during the study period. I have written a paper on this research but have not yet submitted it for publication.

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Durski, S. and S. Glenn, 1977. Observations of the New York Bight apex via thermal infrared satellite imagery. (In preparation)

Presentations at conferences and seminars

Durski, S. Modeling coastal upwelling off New Jersey. AGU 1996 Fall Meeting, San Francisco, CA.

Durski, S. A model of Summer Circulation in the New York Bight - Some sensitivity studies. 1997 Gordon Research Conference, New London, NH.

Conferences attended

Mathematical Modelling of Plankton Population Dynamics, Isaac Newton Institute for Mathematical Studies, University of Cambridge. August 12th - August 23rd 1996

Coastal Ocean Circulation. Gordon Research Conference, Colby Sawyer College, New London, NH. June 15th-20th 1997